Graptolite faunas at the base of the Silurian

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Synopsis

The base of the Silurian System is globally defined by the appearance of a number of species of graptoloid referable to the genera *Akidograptus* and *Parakidograptus*, as well as by a pronounced increase in species diversity from the underlying *persculptus* Zone. The nature of this diversity is given in terms of distinctive elements of the *acuminatus* Zone, in terms of its less diagnostic species, and in terms of species of local occurrence. Contrasts are made with the graptoloid faunas of the *persculptus* and *atavus* Zones.

Introduction

The ratification by the International Commission on Stratigraphy of the base of the Silurian System at the base of the *acuminatus* Zone at Dob's Linn, Scotland, greatly facilitates international correlation of the base in the graptolite facies. Even in sections with only moderately abundant or diverse graptolite associations, the *acuminatus* assemblage can usually be identified, although not always the precise lower and upper limits of the zone: the approximate correlative level is often quite clear. Furthermore, the distinctive nature of the *acuminatus* fauna makes relatively simple the present task, namely that of defining the base of the Silurian in terms of its graptolites. It should not be assumed that the base of the *acuminatus* Zone corresponds with the beginning of the post-glacial evolutionary explosion in graptoloids (Koren & Rickards 1979): that precise level is probably near the base of the *persculptus* Zone, using that term in its broadest sense. The lowest graptoloid diversity corresponds roughly with the *extraordinarius* Zone. This was followed by an increased diversity in the *persculptus* Zone, and a yet greater increase in the *acuminatus* Zone. It is the last that now identifies the base of the Silurian and which is described below.

It is helpful that the *acuminatus* Zone was originally defined at Dob's Linn (Lapworth 1878). However, he included at its base gingerbread-coloured shales which Jones & Pugh (1916) considered equivalent to Jones' (1909) *persculptus* Zone at Port Erwyd. This opinion was amply reinforced by Davies (1929), Toghill (1968) and Williams (1983), so that the original concept of the zone has been changed to mean the graptolite faunal assemblage between the *persculptus* and *atavus* Zones or their equivalents.

Graptolites immediately preceding the *acuminatus* Zone

Low diversity characterizes both the *extraordinarius* and *persculptus* Zones. There is a total absence of multistiped genera such as *Dicellograptus* and *Tangyagraptus*, and the *extraordinarius* Zone comprises only a few biserial types, including *C. extraordinarius* together with diminutive climacograptids such as *C. normalis*, *C. angustus* (= *C. miserabilis*) and *C. mirnyensis*. *C. medius* appears near the top of the zone in northeastern U.S.S.R. The *persculptus* Zone has a fauna a little more diverse than that of the *extraordinarius* Zone, but apart from rare uniserial scandent forms (*Atavograptus ceryx* and similar species) comprises biserials, including the three just listed for the *extraordinarius* Zone, but excluding *C. extraordinarius*. *Glyptograptus persculptus* itself and several closely related forms typify the *persculptus* Zone, but at least one subspecies persists into the *acuminatus* Zone. Thus the *persculptus* fauna is similar to the *extraordinarius* fauna, but differs in having the first uniserial scandent species, the very beginning of a major evolutionary explosion of these forms, and more numerous biserial species, especially glyptograptids.

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Distinctive features of the *acuminatus* Zone

The base of the zone is defined by the appearance of biserial graptolites with a characteristic drawn-out, thorn-like proximal region involving elongate sicula, elongate early thecae and a pronounced alternating arrangement of the thecal apertures. Two genera are involved: *Akidograptus* (type species *A. ascensus* Davies) with climacograptid-like thecae, and *Parakidograptus* (type species *P. acuminatus* (Nicholson)) with orthograptid-like thecae. In the lower half of the zone *A. ascensus* is usually much more abundant than *P. acuminatus*, the reverse obtaining in the upper part of the zone. However, in sections with somewhat depleted diversity the two may appear in sequence with a relatively short period of overlap. It cannot be emphasized too strongly that in richly graptolitic sections the two species seem to occur throughout, with *A. ascensus* perhaps becoming extinct a little before *P. acuminatus*.

An additional parakidograptid *P. acuminatus praematurus* was described by Davies (1929) from the lower half of the zone. Although this form has not yet been widely recorded, it has considerable potential for correlation because it is a (morphologically) earlier form than the type subspecies, having a less protracted proximal end which clearly indicates a typically more robust biserial ancestor. It is likely that *P. a. praematurus* is restricted to the lower half of the *acuminatus* Zone.

Another rare species occurring in the lower part of the *acuminatus* Zone is *Atavograptus ceryx*, although this species is more common in the *persculptus* Zone. From unpublished information and new specimens it seems likely that other, related, uniserially scandent forms will be described from this zone. Subspecies of *G. persculptus* do occur at the base of the *acuminatus* Zone, overlapping with *Akidograptus* and *Parakidograptus*, but there are also a number of other undescribed glyptograptids in both the *acuminatus* and *persculptus* Zones, often referred to as *G.* ex gr. *tamariscus*. Elucidation of these will clearly help refine correlation. *G.? avitus* extends into the lower half of the zone from the *persculptus* Zone.

C. trifilis is recorded from the middle of the *acuminatus* Zone. This tiny form has a striking three-fold spine at the base of the rhabdosome, presumably involving virgellar and antivirgellar spines. Its relationship to *C. tuberculatus* from the *persculptus* Zone is not clear; and it should be said that multispinose biserials in the Silurian are in general need of revision, as implied by Rickards & Koren (1974). *Cystograptus vesiculosus*, which lends its name to the succeeding zone in some broader zonal scenarios, occurs first of all in the upper part of the *acuminatus* Zone, as does *Climacograptus rectangularis*, a presumed derivative of the earlier *C. medius*.

Finally in this section we should mention *Orthograptus truncatus* (= *O. amplexicaulis*), *sensu lato*, which has been widely recorded from both the *persculptus* and lowest *acuminatus* Zones. The taxonomic positions of these forms are uncertain: certainly forms I recently recorded from Northern Ireland lack the proximal end spinosity of typical, earlier species, and in this sense at least are more characteristically Silurian. The same is true of Hutt's (1974) recordings of *O. t. abbreviatus*.

Less diagnostic species of the *acuminatus* Zone

The most common species in most assemblages are relatively small climacograptids which extend upwards from the Ordovician. Typical amongst these are *C. normalis* Lapworth, *C. angustus*, *C. innotatus* Nicholson and the more robust *C. medius*. In addition the diplograptids *D. modestus* and *D. diminutus* occur, the second possibly appearing in the *acuminatus* Zone, though I hesitate to claim this with the certainty the literature suggests, simply because the group is in dire need of revision. Other forms related to *C. innotatus* (sometimes referred to the genus *Paraclimacograptus*) may occur, and I have already mentioned the undescribed glyptograptids. In addition a number of sections round the world have a smaller number of forms seemingly referable to the genus *Pseudoclimacograptus* (see next section). All the forms listed in this section range upwards into the *atavus* Zone, and in some cases higher.

Species of local occurrence

In addition to the above species, modern work in several parts of the world has resulted in the recognition of what are, at present, species of relatively local occurrence. Thus *Pseudoclimacograptus* (*P.*) *orientalis* occurs in the Soviet Union, and may possibly do so in Poland (Rickards 1976: 159). In the Kolyma region Obut *et al.* (1967) record *A.* aff. *priscus* and *Orthograptus sinitzini* as well as *C. mirnyensis*. The relationship of *Orthograptus sinitzini* to *C. tuberculatus* has never been clarified and is another area worthy of further investigation, and in the recent account of the geology of northeastern U.S.S.R. (Koren *et al.* 1983) *P.* aff. *acuminatus praecedens* is recorded. Of pseudoclimacograptids Koren & Mikhailova (1983) have recorded *P. fidus* and *P. pictus*, and like forms have been found recently in the type Llandovery area (Cocks *et al.* 1984).

Waern (1948), in a careful revision of *normalis*-like climacograptids, described *C. praemedius* and *C. transgrediens*, and also recorded *C. indivisus* Davies (previously only known from the *persculptus* Zone).

The latest records from China are summarized by Mu (this volume), but it is worth noting especially that several additional records of akidograptids have been made, such as *A. xixiangensis* Yu *et al.* and *A. parallelus* Li & Jiao, as well as other biserial species as yet listed only from China. It appears correct to say that China is the only country to date with a record of the typical late Ordovician genus *Paraorthograptus* in the Silurian, i.e. in the *acuminatus* Zone. Mu (this volume) also notes the presence of several subspecies of *G. tamariscus*, but whether they are related to the later evolutionary burst of that group is not discussed.

Top of the *acuminatus* Zone

It is necessary by international agreement to define only the base of a zone. Nevertheless, it is useful here to outline what distinguishes the *acuminatus* Zone from the overlying *atavus* Zone. Basically the demise of the akidograptids is followed by increased diversification of the uniserial scandent monograptids belonging to several genera (*Atavograptus*, *Lagarograptus* and *Coronograptus*) as well as by numbers of dimorphograptids. Only in one section have akidograptids been recorded from the *vesiculosus* Zone, namely in Sardinia (Jaeger 1976). There is some overlap, naturally, but the two faunas could hardly be much more different than they are.

Finally it is clear that the *acuminatus* Zone is capable of being subdivided in useful fashion, a step already taken by Teller (1969) for example, and in effect, by Stein (1965; see also Jaeger, this volume). In most sections a lower, middle, and upper part can be identified, not only upon the occurrence of akidograptids and parakidograptids, but also on the occurrence of such species as *A. ceryx*, *C. trifilis*, *Cy. vesiculosus*, *C. rectangularis* and so on. The revision of other groups, so necessary at present, will undoubtedly increase the potential not only for international correlation at this level, but also for subdivisions of the presently defined *acuminatus* Zone.

Conclusions

The *acuminatus* fauna is not only distinctive and easily recognizable, but is widespread in the world, as the other sections in this volume make clear. The akidograptids and parakidograptids, whatever the species or subspecies, seem to be almost totally restricted to the zone. The zonal assemblage forms not only a gradual change between the *persculptus* and *atavus* Zones, but represents a distinctive stage in the evolution of Silurian graptoloids reflecting a very advanced stage of post-glacial marine transgression and the development of widespread anaerobic black shales and the re-establishment of a rich, marine, tropical plankton.

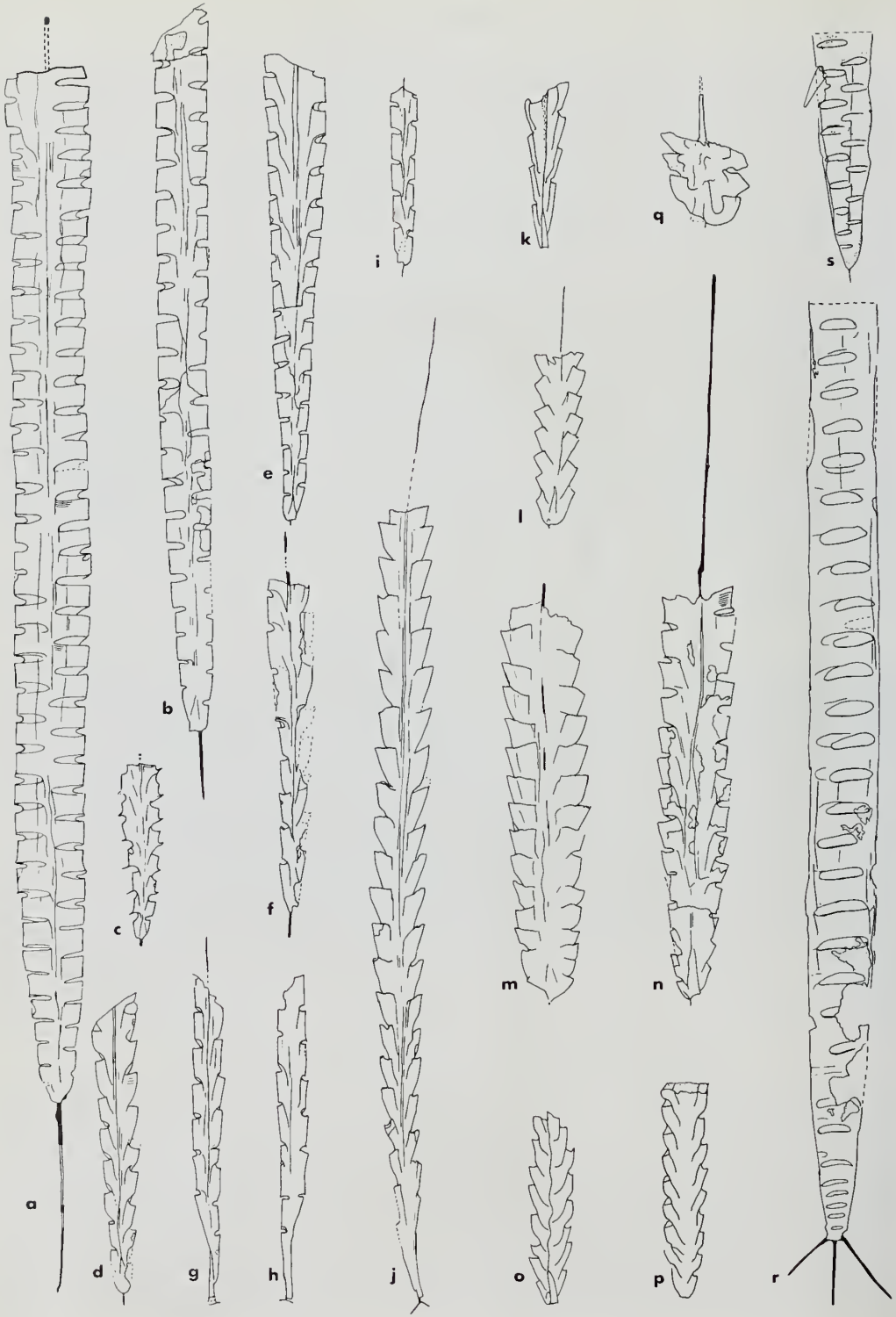
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Fig. 1 Typical *acuminatus* Zone assemblage. Specimens in Sedgwick Museum, Cambridge. a, *Climacograptus medius* Törnquist, A20150; b, *Climacograptus normalis* Lapworth, A20090; c, *Paraclimacograptus innotatus* (Nicholson), A20226; d, *Glyptograptus* sp., X.9999; e, *Climacograptus rectangularis* M'Coy, A20067; f, *Glyptograptus avitus* Davies, A10019, figd Davies, 1929: 8, fig. 21; g, h, part and counterpart of *Akidograptus ascensus* Davies, X.9996a, b; i, *Climacograptus angustus* Perner (= *C. miserabilis* Elles & Wood), X.9993; j, *Parakidograptus acuminatus* (Nicholson), A75394; k, *Parakidograptus praematurus* (Davies), A10023, figd Davies, 1929: 10, fig. 25; l, *Orthograptus* sp. (? ex gr. *amplexicaulis* Hall), X.9995; m, n, *Diplograptus modestus* Lapworth, respectively A20425 & A20428; o, p, *Glyptograptus persculptus* (Salter), *sensu lato*, figd Davies, 1929: 14, respectively figs 15 and 20 as 'mut. omega', A10013 and A10018, the latter being regarded as holotype; q, *Cystograptus vesiculosus* (Nicholson), X.9994; r, s, *Climacograptus trifilis* Manck, respectively X.9998 and biprofile view showing virgellar spine only, X.9997. All figures × 5.